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# WIND PROFILER/RASS OBSERVATIONS OF DEEP CONVECTION

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## 1. Introduction

There has been a sequence of experiments aimed at improving our understanding of tropical thunderstorms. For example, an experiment combining polarimetric radar and multiple frequency wind profiler observations was performed in 1997 near Darwin, northern Australia with the aim of characterizing the vertical motion and microphysical structure of storms and comparing polarimetric (see Keenan et al., 1998) and profiler observations of quantitative rainfall, drop size and mixed phase (May et al., 2001). A weakness of these experiments has been the lack of thermodynamic data to support the kinematic storm analyses, To try and address this, there have been two experiments aimed at extending these studies to include thermodynamic information through the use of 50 MHz RASS (Radio Acoustic Sounding System) observations in January/February 2000 and 2001. This allows the direct measurement of the virtual temperature profile within the convection. This combined with the precipitation and vertical motion information gives a fairly complete picture of the internal structure of the storms. One case from each of these periods will be discussed. The first case is observations of a cell that in a squall line that was decaying as it moved over the profiler and the second was an isolated active deep cell.

## 2. Profiler analysis techniques

There are two wind profiler radars located near Darwin, one operating at 50 MHz and the other at 920 MHz. The 920 MHz system was operating in a fixed 2 minute cycle with a 45 s long vertical sampling followed by a 15 s off vertical record while the 50 MHz RASS records were approximately 30 s long. The 50 MHz clear air signals are used to measure the vertical motion. The 920 MHz profiler is used as a vertically pointing Doppler weather radar to measure the reflectivity weighted fall speed spectrum. The reflectivity weighted fall speed spectrum is used to estimate hydrometeor size distributions. We use a similar technique that is described by Gossard (1988) to remove the effects of turbulence using the 50 MHz profiler data. Plans include using dual frequency methods.

These experiments represent the first time that a 50 MHz RASS has been systematically applied during significant convection. The RASS coverage would be expected to be very good in the tropics except in tropical cyclones because of the relatively weak horizontal winds (May et al., 1988). However, the height coverage is patchy in nature and has limited vertical extent (~2-5 km). The first year we used a single source, but the second used multiple sources with little improvement.

## 3. Results

Two cases will be discussed. The first was collected during the passage of a monsoonal squall line approaching from the north in 2000. The second case from 2001 will be briefly discussed to show some problems and limitations with the measurements and is of more active deep convection. At the time of its passage over the profiler, the main convection was beginning to decay. Fig 1 shows time height cross-sections of the 920 MHz radar reflectivity, vertical motion and virtual temperature during the storm passage. The main convective band was overhead between 0630 and 0655 with no bright-band and relatively strong vertical motions. A brief transition zone was seen between 0655 and 0700, still with no brightband, but weak vertical motion. After 0700, heavy stratiform rain begins with an intense brightband evident. After 0730, there was light stratiform rain with the bright band still present, but only weak vertical motion and weakening echoes.

The maximum vertical velocities are relatively weak with maximum amplitudes less than 5 ms$^{-1}$. Furthermore it is clear in this figure that the convective downdraft has essentially undercut the entire storm and the process of decay into a stratiform rain region has begun. This is frequently seen in profiler data taken in this area (May and Rajopadhyaya, 1999). Although it is not clear in this figure, the temperature within the convection was about 0.5 - 1.0$^{o}$C warmer than the surrounding areas. However, there is a distinct negative correlation between vertical velocity and temperature perturbations seen within the storm. We had expected the reverse to be the case and the RASS analysis has been carefully checked to ensure that vertical motion is properly corrected for. The regions with the largest vertical motion is characterised by the largest lapse rates and are moist unstable. In cloud regions of small vertical motion are typically 1-2 $^{o}$C/km more stable. Note that with 50 MHz RASS the minimum height that is sampled is about 1.5 km above the ground and hence above any convectively generated cold pool. There may also be issues related to the fact that the storm is decaying indicating the loss of thermodynamic support for the convection and the negative correlations may be a reflection of this.

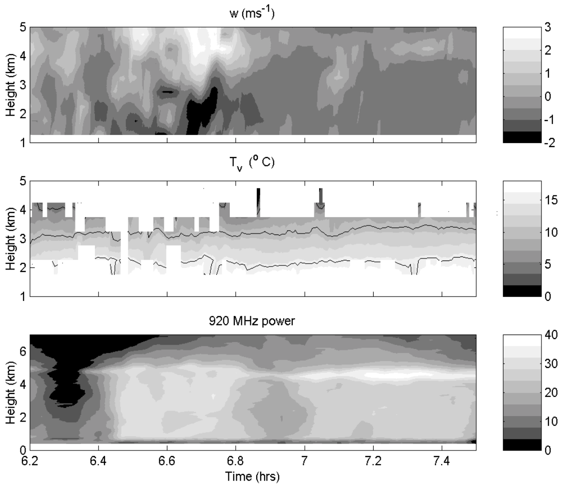

**Figure 1** Time height cross-sections from Feb 8, 2000

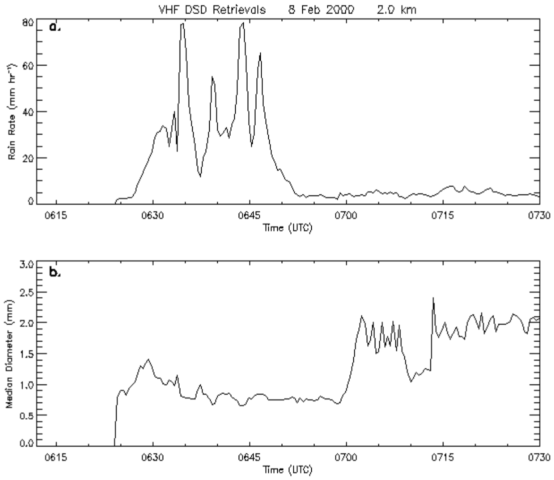

**Figure 2** Profiler estimates of rain rate and median volume diameter.

With the relatively small amplitude vertical motions there is no sign of the production of large ice that was noted in the study of the small intense thunderstorms in either the profiler or polarimetric radar data. Differences in DSD parameters in the different rain regions are very apparent. In the convective region both the DSD slope and intercept tend to increase. Slope ranges between 3 and 5, large values of the intercept parameter( n0: 10000 to 1000000), i.e. many small drops and relatively few large drops giving a small median diameter. There is a distinct transition into the stratiform region with relatively few drops altogether (low n0) and relatively more large drops (small slope). The preponderance of large drops is reflected in median diameter. This 'regime' lasts until about 0745, where intercept and slope move to intermediate values during last portion of stratiform stratiform rain. These numbers and behavior compare well with the previous literature, particularly the dichotomy between the convective and stratiform regions.

The second case to be discussed is associated with a deep convective cell and heavy rain. Detailed analysis has not yet been done for this case, but there is sufficient information to raise some issues with this experiment. The most convectively active time is shown in Fig. 3 with updrafts in

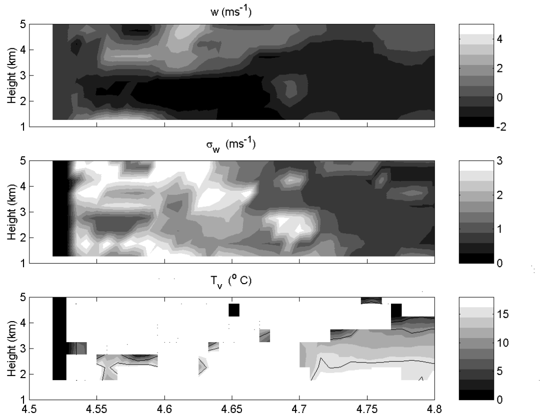

**Figure 3** Time height cross-sections of vertical velocity (top) spectral width(centre) and RASS virtual temperatures (bottom) measured with the 50 MHz profiler during a thunderstorm on February 7, 2001

excess of 6 $ms^{-1}$. Also shown is the clear air spectral width. For these measurements this is dominated by turbulence and temporal variability (time resolution is 30 s). The widths during the convection are large and variable, typically being several $ms^{-1}$. At this time the RASS signals completely disappear. This behaviour was seen in the 2000 experiment and in other events during 2001. We hypothesize that the loss of signal is associated with turbulent distortion of the acoustic waves decreasing the RASS intensity. This has yet to be tested, and a counter argument must be the usefulness of higher frequency RASS measurements including highly turbulent regimes such as gust fronts (e.g. May, 1999). It does not seem to be related to the presence of rain because reasonable signals have been observed in heavy stratiform rain and the decaying convection case discussed in detail above, although the rain rates are somewhat less than the intense convective cases.

## 4. Conclusions

These data show some results from a systematic attempt to measure the vertical motion, thermal structure and precipitation characteristics within convection. The results clearly indicate that there is potential for these measurements, but that there is a need for further experimentation. In particular the negative correlation between temperature and vertical motion is puzzling. This has been observed in some aircraft data, but is not usual. Further experiments are required with improved RASS instrumentation, particularly more and better RASS sources. There is a need to sample more intense convection and for theoretical calculation of RASS signal loss in very turbulent conditions.

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